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A Method for Assessing the Environmental Sensitivity of Land to Forest Harvesting in Central and Western Newfoundland

A.R. van Kesteren

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A METHOD FOR ASSESSING THE ENVIRONMENTAL SENSITIVITY OF LAND TO FOREST HARVESTING IN CENTRAL AND WESTERN NEWFOUNDLAND

by A.R. van Kesteren

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ABSTRACT

A method of mapping relative landscape sensitivity using conventional aerial photography at scales of 1:10 000 to 1:30 000 is presented. Six levels of sensitivity are derived from various combinations of soil erodibility, slope and groundwater conditions. Maps generated from this method can be used in conjunction with operational guidelines to minimize ground disturbances associated with forest harvesting. These maps can also be used in the planning stages of forestry operations to assist in the location of environmentally sound road and stream crossing locations.

RÉSUMÉ

Les auteurs présentent une méthode de cartographie de la sensibilité relative du terrain, à l'aide de photos aériennes conventionnelles à des échelles de 1:10 000 à 1:30 000. Ils ont dérivé six niveaux de sensibilité d'après les diverses combinaisons d'érodabilité, de pente et de conditions des eaux souterraines. Les cartes établies à partir de cette méthode sont utilisables avec les lignes directrices opérationnelles afin de réduire au minimum les dérangements de sol associés à la récolte forestière. Ces cartes peuvent également servir à planifier les exploitations forestières en facilitant la localisation des routes et des ponts aux endroits les moins nuisibles pour l'environnement.

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INTRODUCTION

The Newfoundland Forestry Centre has carried out several studies related to logging disturbance and have developed guidelines to prevent some of these disturbances (Wells and Roberts 1973; Case and Rowe 1978; Case and Donnelly 1979). The conclusions of Case and Donnelly (1979) are particularly relevant to the impact of logging disturbance on future forest productivity.

> "In the final analysis skidder logging operations following conventional procedures create ground disturbances which could result in substantial site deterioration and reductions in long-term site productivity. Consequently, every effort must be made especially under intensive forest management, to minimize impacts by reducing site damage at the operational stage in timber harvesting."

In addition to the direct impact on the forest land base, there can be other serious impacts on fish habitat through stream siltation and wildlife in general because of changes in the composition of the vegetation habitat and traditional routes for ungulate migration.

Environmental guidelines (Case and Rowe 1978; McCubbin et al. 1985) provide one means of minimizing site damage through enhancement of proper road construction. However, casual observation of logged-over areas suggests another dimension to the problem which is related to the overall road network design and logging procedures followed. Addressing these additional concerns requires a planning perspective which approaches the problem from a broader scale.

Traditionally, the planning of logging operations has been motivated by economic and engineering considerations related to extraction of the current harvest. Logging plans which account for environmental concerns arising from road layout and harvest operations would of necessity have to incorporate a long-term ecological perspective. Integrating the relationships between ecological variables and forest engineering criteria in a mapping system provides an approach for addressing environmental concerns inherent in logging operations. If successful, this approach could be incorporated into the planning process with the result of increasing harvest efficiency, reducing site disturbance and maintaining long-term forest productivity.

BACKGROUND

In April 1983 the Canadian Forestry Service and the Lands and Integrated Programs Directorate, Environment Canada initiated a study to assess the potential for mapping environmental considerations in logging operations. Government and industry officials were asked to suggest potential study locations.

Two study areas were chosen and field investigations were undertaken in the fall of 1983. The observations of the study team revealed the difficulties of incorporating environmental design into logging operations and also demonstrated the relationship between ground disturbances and inherent site conditions.

In November 1983 an advisory committee was established to provide direction and periodically review the progress of the study.

APPROACH

Environmental sensitivity of land to forest harvesting can be thought of as a specific land use problem. In recent years land use and evaluation studies have been conducted through recognized and accepted ecological land classification methods. These methods make frequent use of conventional air photo interpretation techniques thus having a wide extrapolative value. Ecological land classification systems which are organized in a hierarchical format have well defined levels of mapping based upon the interrelationships between biotic and abiotic features of the biosphere.

Within the framework of the ecological land classification system relative land sensitivity ratings were derived at the ecosite level based upon three easily recognized parameters: relative soil erodibility (inferred from soil texture), slope and groundwater condition. The term ecosite traditionally includes the vegetation-soil series relationship but these variables were not considered to have a direct influence on the derivation of the land sensitivity ratings. However, the work of Damman (1964, 1967) demonstrates that catenary relationships are directly related to soil texture, slope and groundwater conditions, thus providing a reliable data base for ecosite delineation.

Relative erodibility of a soil has a direct relationship to its texture. There are also direct relationships between geomorphic processes both past and present, and the texture of soils which constitute the resultant landforms. These relationships provide a basis for determining relative soil erodibility.

Slope gradient and length influence soil erosion. Generally, as slope length and gradient increase other factors being held constant, soil loss increases. Gradient was estimated directly by slope classes. Slope length was not measured directly but is inherent in the various ecosite delineations.

Groundwater conditions and soil moisture content have important implications for soil bearing capacities and potential site damage. Moreover, soils with naturally high antecedent moisture contents allow less infiltration thus increasing the potential for overland flow and potential soil loss.

The interrelationships among relative soil erodibility, slope gradient and soil moisture condition and the relative ease of detection of these parameters through conventional air photo interpretation provide the basis of approach.

STUDY AREAS

Three factors were considered in selection of the study areas:

1. The areas were to be representative of landscape conditions in central and western Newfoundland.

2. The areas were not to be ones in which environmental impact assessments were proposed or ongoing.

3. The areas selected were to be ones with scheduled logging operations, thus affording the opportunity to carry out mapping before ground disturbance and to observe the effects of logging in relation to the completed mapping.

Two areas were chosen for study, one on Abitibi-Price limits in central Newfoundland and the other on Corner Brook Pulp & Paper Limited limits in western Newfoundland (Figure 1). The central Newfoundland area borders the Northwest Gander River and extends south and eastward to Little Gander Pond and Newton Lake, respectively. This area is a rolling plateau which reaches an elevation of 300 m above sea level. The area is characterized by a complex of igneous and metamorphic formations including granite, gneiss and slate. Moderately deep to deep tills interspersed with frequent occurrences of hummocky melt-out till and glaciofluvial deposits comprise the dominant surficial geological features. Major organic deposits in the form of domed bogs and accumulations of alluvial parent materials in association with water courses are present throughout the area. The most common cover type is black spruce (Picea mariana (Mill.) B.S.P.). Stands of pure balsam fir (Abies balsamea (L.)

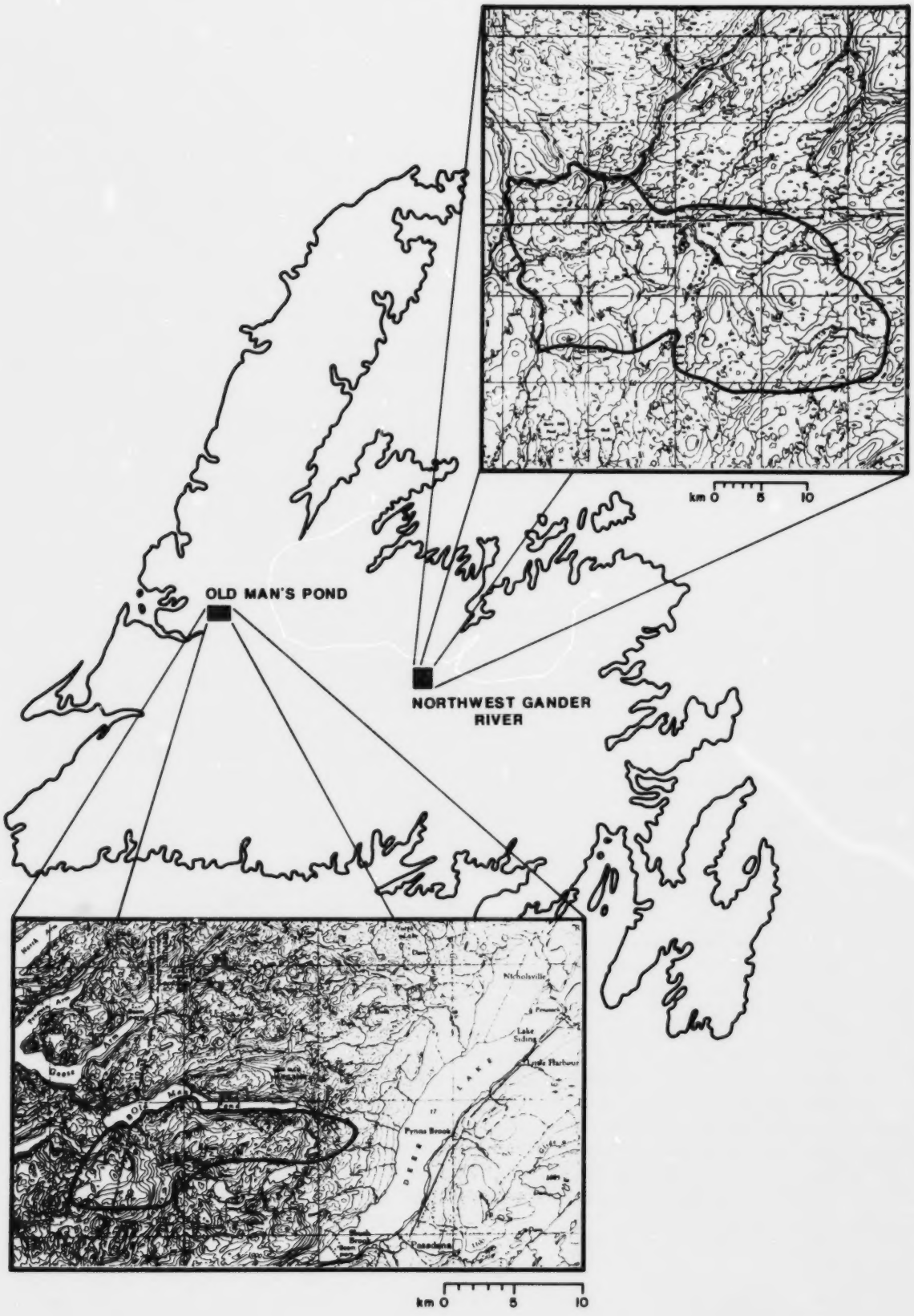


Figure 1. Pilot study areas at Old Man's Pond in western Newfoundland and Northwest Gander River in central Newfoundland.

Mill.) or balsam fir stands with significant percentages of white birch (Betula papyrifera Marsh.) occur less frequently and are generally restricted to river valleys. This mosaic of vegetation has resulted primarily from fire and represents a common forest cover pattern for central Newfoundland.

The western Newfoundland area borders the southside of Old Man's Pond. This area is characterized by a hilly topography which reaches an elevation of 425 m above sea level. The area is predominantly sedimentary consisting of shale, sandstone, limestone and dolomite rock types. The surficial geology is dominated by complexes of glacial till and colluvium on steep slopes, whereas summits have a thin to moderately deep cover of glacial till. Organic landforms are primarily sloped fens, while accumulations of alluvial material are usually present in sinuous stream reaches. The forest cover is predominantly a balsam fir - white birch mixture. Black spruce usually occupies marginally productive to non-merchantable sites. The balsam fir - white birch association in western Newfoundland contrasts with the black spruce cover types of central Newfoundland.

METHODS

Derivation of the Land Sensitivity Levels

The first step in the development of a method for determining relative land sensitivity was to assign a range of values that could be clearly distinguished through air photo interpretation. Six levels of relative land sensitivity were recognized:

L_0 - none
L_1 - low
L_2 - moderate
L_3 - high
L_4 - very high
L_5 - extreme

Three parameters were utilized to derive the land sensitivity levels:

1. Relative soil erodibility - E
2. Slope class - S
3. Groundwater class - G

Appendices I, II and III describe these parameters in greater detail.

The parameters were subdivided as follows:

Relative Soil Erodibility - (E)	Slope Class - (S)	Groundwater Class - (G)
E_0 - none	S_0 - negligible (0-5%)	G_0 - no predominant groundwater influence in soil profile
E_1 - low	S_1 - low (6-15%)	
E_2 - moderate	S_2 - moderate (16-30%)	G_1 - lateral seepage of soil water (interflow)
E_3 - high	S_3 - high (31-45%)	G_2 - perched or true groundwater influence in soil profile
	S_4 - very high (46-60%)	$G_2(i)$ - Class G_2 with periodic inundation
	S_5 - extreme (>60%)	

Table 1 shows the relationship of relative soil erodibility to pedologic and geomorphic conditions.

The parameter subdivisions were combined as shown in Figure 2. Table 2 shows all the combinations and the corresponding sensitivity levels. The determination of the parameter combination provides the basis for interpretation and assignment of a particular sensitivity level to an ecosite.

Derivation of the Ecosite Groups

The next step in developing a rating system was the synthesis of the various parameter combinations into groups. These groups consist of ecosites characterized by similar ecological conditions. Thus, the ecosites comprising a group could be expected to react similarily to a particular form of disturbance and therefore a specific mitigative guideline would apply. Table 3 shows the various ecosite groups and subgroups (from a to f) along with a summary of their related ecological conditions.

Land Sensitivity Rating

The land sensitivity ratings were derived by combining sensitivity levels and ecosite groups. The final rating defines the relative degree of sensitivity and details the predominant site conditions for a delineated map unit.

Figures 3 and 4 illustrate the application of the final sensitivity ratings to representative landscapes in central and western Newfoundland. Figure 5 is an example of land sensitivity mapping in the central Newfoundland study area.

Table 1. Relationship of relative soil erodibility to pedologic and geomorphic conditions.

Relative erodibility	Particle size class[1] Field Texture[2]	(Symbol)	Genetic category[3]	Probable textural classes and (inclusions)
E_0 (none)	Consolidated bedrock			
	Unconsolidated rock			
	Blocky (angular, size > 256 mm)	(a)	Rock	Consolidated bedrock and unconsolidated
	Bouldery (rounded, size > 256 mm)	(b)	Alluvial	rock; non soil: unconsolidated mineral
	Rubbly (angular, size > 2-256 mm)	(r)		and/or organic materials 10 cm in
	Gravelly (rounded, size > 2-256 mm)	(g)		depth a, b, r, g
E_1 (low)	Coarse sand	(cos)	Alluvial	cos, s, fs, vfs (g, b)
	Sand	(s)	Eolian	cos, s, fs, vfs
	Fine sand	(fs)	Glaciofluvial	cos, s, fs, vfs (g, b)
	Very fine sand	(vfs)	Morainal	cos, s, fs, vfs (r, a)
E_2 (moderate)	Loamy coarse sand	(lcos)	Alluvial	lcos, ls, lfs, lvfs (g, b)
	Loamy sand	(ls)	Glaciofluvial	lcos, ls, lfs, lvfs (g, b)
	Loamy fine sand	(lfs)	Morainal	lcos, ls, lfs, lvfs cosl, sl, fsl, vfsl
	Loamy very fine sand	(lvfs)		(r, a)
	Coarse sandy loam	(cosl)	Colluvial	lcos, ls, lfs, lvfs, cosl, sl, fsl, vfsl
	Sandy loam	(sl)		(r, a)
	Fine sandy loam	(fsl)	Organic	of
	Very fine sandy loam	(vfsl)		
	Organic	(o)		
	fibric	(of)		
E_3 (high)	Loam	(l)		
	Silt loam	(sil)		
	Silt	(si)	Morainal	l, sil, scl, fscl, vfscl, cl, sicl, sc,
	Sandy clay loam	(scl)		sic, c (r, a)
	Fine sandy clay loam	(fscl)	Colluvial	l, sil, scl, fscl, vfscl, cl, sicl, sc,
	Very fine sandy clay loam	(vfscl)		sic, c (r, a)
	Clay loam	(cl)	Alluvial	l, sil, si (g, b)
	Silty clay loam	(sicl)	Lacustrine	si, c (cos, s, fs, vfs)
			Marine	si, sc, sic, c, hc (cos, s, fs, vfs)
	Sandy clay	(sc)	Eolian	l, sil, si
	Silty clay	(sic)	Organic	cm, oh
	Clay	(c)		
	Heavy clay	(hc)		
	Organic	(o)		
	mesic	(cm)		
	humic	(oh)		

[1]C.S.S.C. 1978.
[2]Day 1983.
[3]Wells et al. 1972.

SOIL ERODIBILITY CLASS

SLOPE CLASS	E_0	E_1	E_2	E_3
S_0	NONE	NONE	LOW	MODERATE
S_1	NONE	LOW	LOW	MODERATE
S_2	NONE	LOW	MODERATE	MODERATE
S_3	NONE	MODERATE	MODERATE	HIGH
S_4	NONE	HIGH	HIGH	HIGH
S_5	NONE	VERY HIGH	VERY HIGH	VERY HIGH

SOIL ERODIBILITY CLASS + SLOPE CLASS

GROUNDWATER CLASS	NONE	LOW	MODERATE	HIGH	VERY HIGH
G_0	L_0	L_1	L_2	L_3	L_4
G_1	L_0 / L_1	L_2	L_3	L_4	L_5
$G_2(i)$	L_0 / L_1 (L_2)	L_2 / (L_3)	L_3 / (L_4)	L_4	L_5

Figure 2. Derivation of levels of sensitivity based on erodibility , slope and groundwater classes.

Table 2. Combinations of parameters (E- relative erodibility, S- slope, G- groundwater) and corresponding land sensitivity levels (L).

$E_0S_0G_0$	$E_0S_0G_1$ *	$E_0S_0G_2$(i)	L_0	L_0	$L_0(L_2)$
$E_0S_1G_0$	$E_0S_1G_1$ *	$E_0S_1G_2$(i)	L_0	L_0	$L_0(L_2)$
$E_0S_2G_0$	$E_0S_2G_1$ *	$E_0S_2G_2$ *	L_0	L_0	L_0
$E_0S_3G_0$	$E_0S_3G_1$ *	$E_0S_3G_2$ *	L_0	L_0	L_0
$E_0S_4G_0$	$E_0S_4G_1$ *	$E_0S_4G_2$ *	L_0	L_0	L_0
$E_0S_5G_0$	$E_0S_5G_1$ *	$E_0S_5G_2$ *	L_0	L_0	L_0
$E_1S_0G_0$	$E_1S_0G_1$	$E_1S_0G_2$(i)	L_0	L_1	$L_1(L_2)$
$E_1S_1G_0$	$E_1S_1G_1$	$E_1S_1G_2$(i)	L_1	L_2	$L_2(L_3)$
$E_1S_2G_0$	$E_1S_2G_1$	$E_1S_2G_2$ *	L_1	L_2	L_2
$E_1S_3G_0$	$E_1S_3G_1$	$E_1S_3G_2$ *	L_2	L_3	L_3
$E_1S_4G_0$	$E_1S_4G_1$	$E_1S_4G_2$ *	L_3	L_4	L_4
$E_1S_5G_0$	$E_1S_5G_1$	$E_1S_5G_2$ *	L_4	L_5	L_5
$E_2S_0G_0$	$E_2S_0G_1$	$E_2S_0G_2$(i)	L_1	L_2	$L_2(L_3)$
$E_2S_1G_0$	$E_2S_1G_1$	$E_2S_1G_2$(i)	L_1	L_2	$L_2(L_3)$
$E_2S_2G_0$	$E_2S_2G_1$	$E_2S_2G_2$ *	L_2	L_3	L_3
$E_2S_3G_0$	$E_2S_3G_1$	$E_2S_3G_2$ *	L_2	L_3	L_3
$E_2S_4G_0$	$E_2S_4G_1$	$E_2S_4G_2$ *	L_3	L_4	L_4
$E_2S_5G_0$	$E_2S_5G_1$	$E_2S_5G_2$ *	L_4	L_5	L_5
$E_3S_0G_0$	$E_3S_0G_1$	$E_3S_0G_2$(i)	L_2	L_3	$L_3(L_4)$
$E_3S_1G_0$	$E_3S_1G_1$	$E_3S_1G_2$(i)	L_2	L_3	$L_3(L_4)$
$E_3S_2G_0$	$E_3S_2G_1$	$E_3S_2G_2$ *	L_2	L_3	L_3
$E_3S_3G_0$	$E_3S_3G_1$	$E_3S_3G_2$ *	L_3	L_4	L_4
$E_3S_4G_0$	$E_3S_4G_1$	$E_3S_4G_2$ *	L_3	L_4	L_4
$E_3S_5G_0$	$E_3S_5G_1$	$E_3S_5G_2$ *	L_4	L_5	L_5

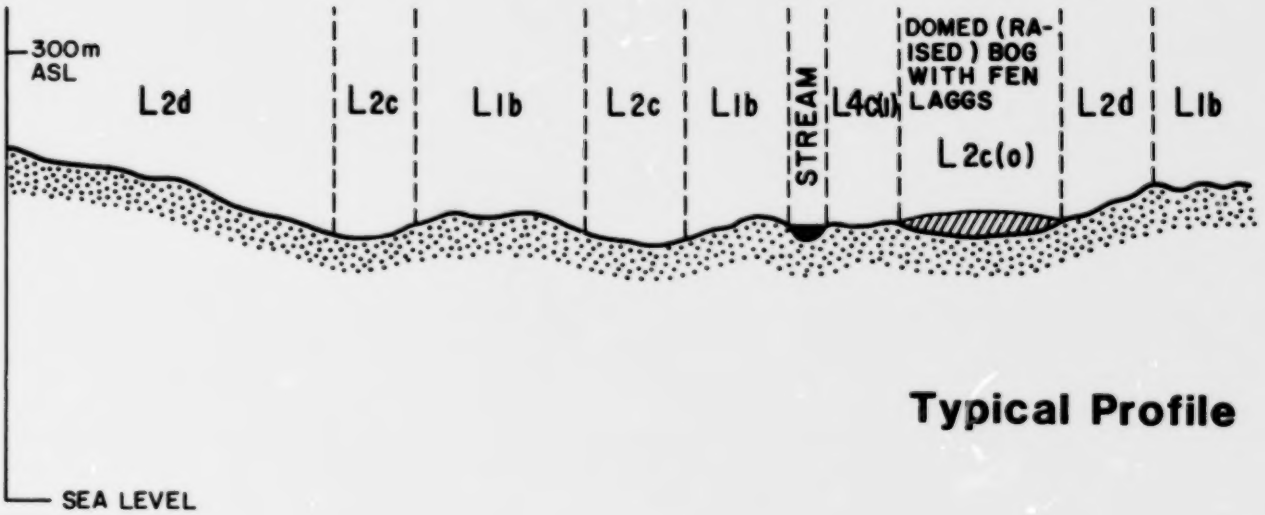
*Occurrence of these combinations improbable under natural conditions.

Table 3. Ecosite groups defined by all combinations of relative erodibility, slope and groundwater.

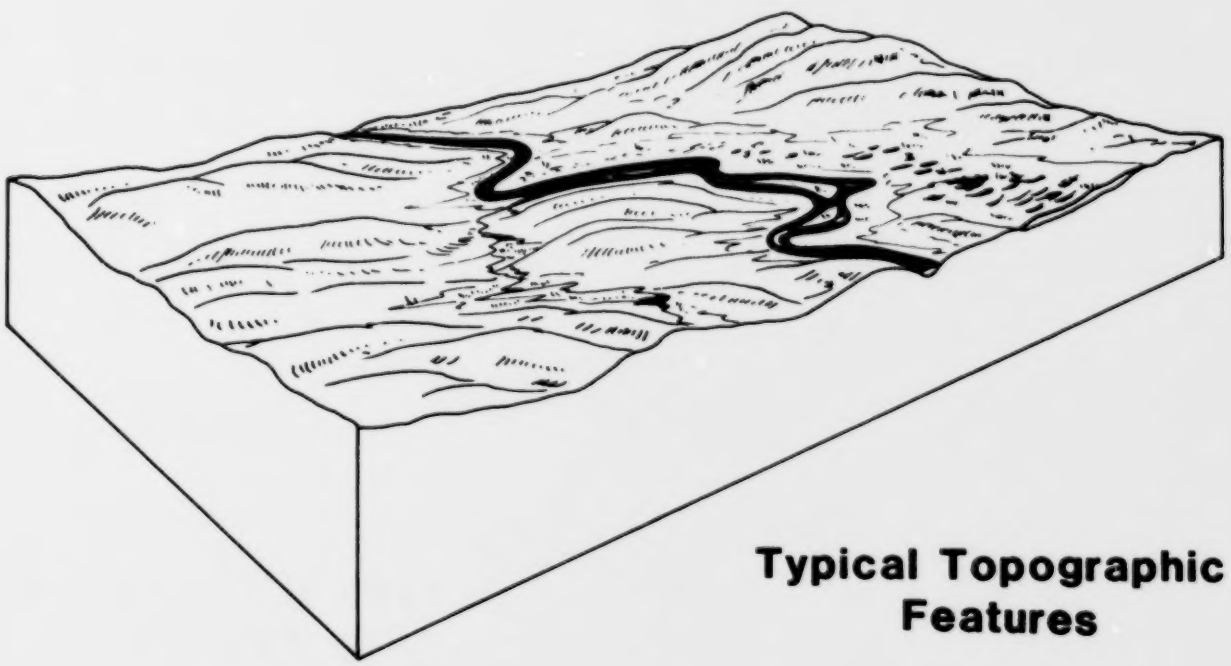
Ecosite groups and subgroups	Parameter combinations and related sensitivity	Summary of ecological conditions
a, a(m)	$E_0S_0G_0$, $E_0S_0G_1$*, $E_0S_0G_2$* $E_0S_1G_0$, $E_0S_1G_1$*, $E_0S_1G_2$* $E_0S_2G_0$, $E_0S_2G_1$*, $E_0S_2G_2$* $E_0S_3G_0$, $E_0S_3G_1$*, $E_0S_3G_2$* $E_0S_4G_0$, $E_0S_4G_1$*, $E_0S_4G_2$* $E_0S_5G_0$, $E_0S_5G_1$*, $E_0S_5G_2$* --- (L_0)	Exposed bedrock or bedrock with < 10 cm cover of organic or mineral material; all slope classes and morphological types included. Subgroup (m), unstable rock subject to mass wasting.
b	$E_1S_0G_0$, $E_1S_1G_0$, $E_2S_0G_0$ $E_2S_1G_0$, $E_3S_0G_0$, $E_3S_1G_0$ --- (L_0, L_1, L_2)	Negligible to low, short, simple and complex slopes; groundwater not present within the soil profile; very rapidly to moderately well-drained; genetic materials predominately morainal or glaciofluvial.
c, c(o), c(l)	$E_0S_0G_2$(i), $E_0S_1G_2$(i) $E_1S_0G_2$(i), $E_1S_1G_2$(i) $E_2S_0G_2$(i), $E_2S_1G_2$(i) $E_3S_0G_2$(i), $E_3S_1G_2$(i) --- (L_1, L_2, L_3, L_4)	Negligible to low slopes with perched soil water or true groundwater; subject to periodic inundation; imperfectly to very poorly drained; variety of soil textures and parent materials. Subgroup c(o), organic soils; subgroup c(l), alluvial mineral soils.
d, d(o)	$E_1S_0G_1$, $E_1S_1G_1$, $E_1S_2G_1$ $E_1S_3G_1$, $E_1S_4G_1$, $E_1S_5G_1$ $E_2S_0G_1$, $E_2S_1G_1$, $E_2S_2G_1$ $E_2S_3G_1$, $E_2S_4G_1$, $E_2S_5G_1$ $E_3S_0G_1$, $E_3S_1G_1$, $E_3S_2G_1$ $E_3S_3G_1$, $E_3S_4G_1$, $E_3S_5G_1$ --- (L_1, L_2, L_3, L_4, L_5)	Slopes that promote subsurface seepage of soil water; genetic materials primarily morainal and/or colluvial; seepage dominant in lower slope positions and less prominent in middle and upper slope positions. Subgroup d(o), organic soils.
e	$E_1S_2G_0$, $E_1S_3G_0$, $E_1S_4G_0$ $E_1S_5G_0$, $E_2S_2G_0$, $E_2S_3G_0$ $E_2S_4G_0$, $E_2S_5G_0$, $E_3S_2G_0$ $E_3S_3G_0$, $E_3S_4G_0$, $E_3S_5G_0$ --- (L_1, L_2, L_3, L_4)	Short, moderate to steep, simple and complex slopes; little or no prominent subsurface seepage due to moderately well-drained to rapidly drained condition of slope.
f*	$E_1S_2G_2$, $E_1S_3G_2$, $E_1S_4G_2$ $E_1S_5G_2$, $E_2S_2G_2$, $E_2S_3G_2$ $E_2S_4G_2$, $E_2S_5G_2$, $E_3S_2G_2$ $E_3S_3G_2$, $E_3S_4G_2$, $E_3S_5G_2$ --- (L_2, L_3, L_4, L_5)	Moderate to steep slopes; perched soil water.

*Occurrence of combinations or groups improbable under natural conditions.

LAND SENSITIVITY
Central Newfoundland



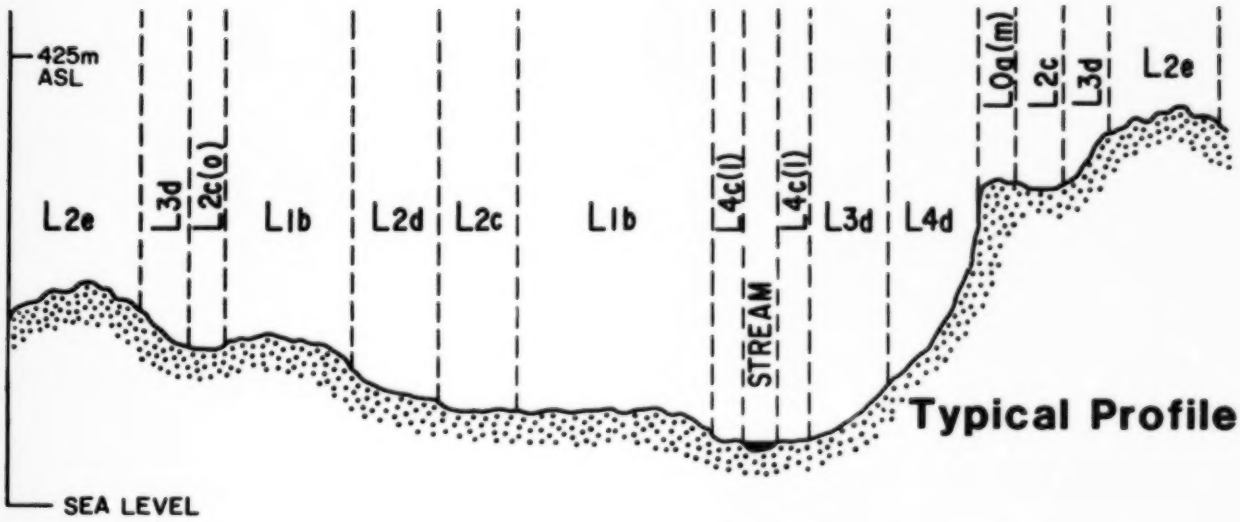
Typical Profile



Typical Topographic Features

Figure 3. Land sensitivity ratings for a representative landscape in central Newfoundland.

LAND SENSITIVITY
Western Newfoundland



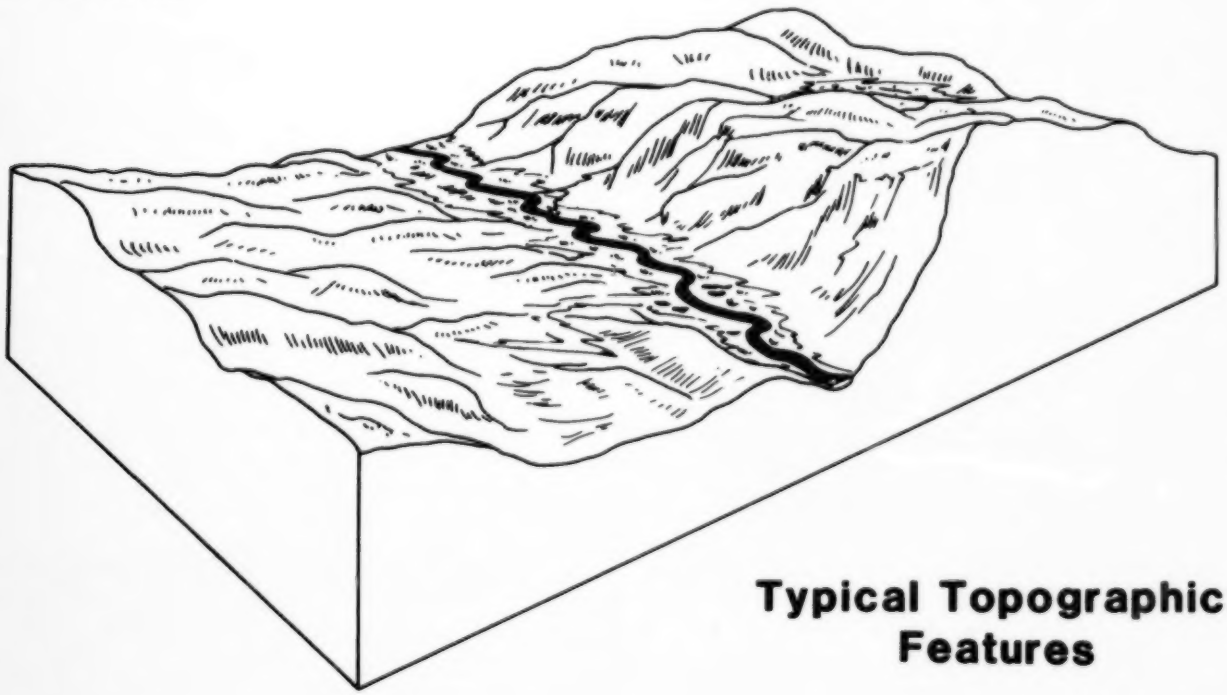


Figure 4. Land sensitivity ratings for a representative landscape in western Newfoundland.

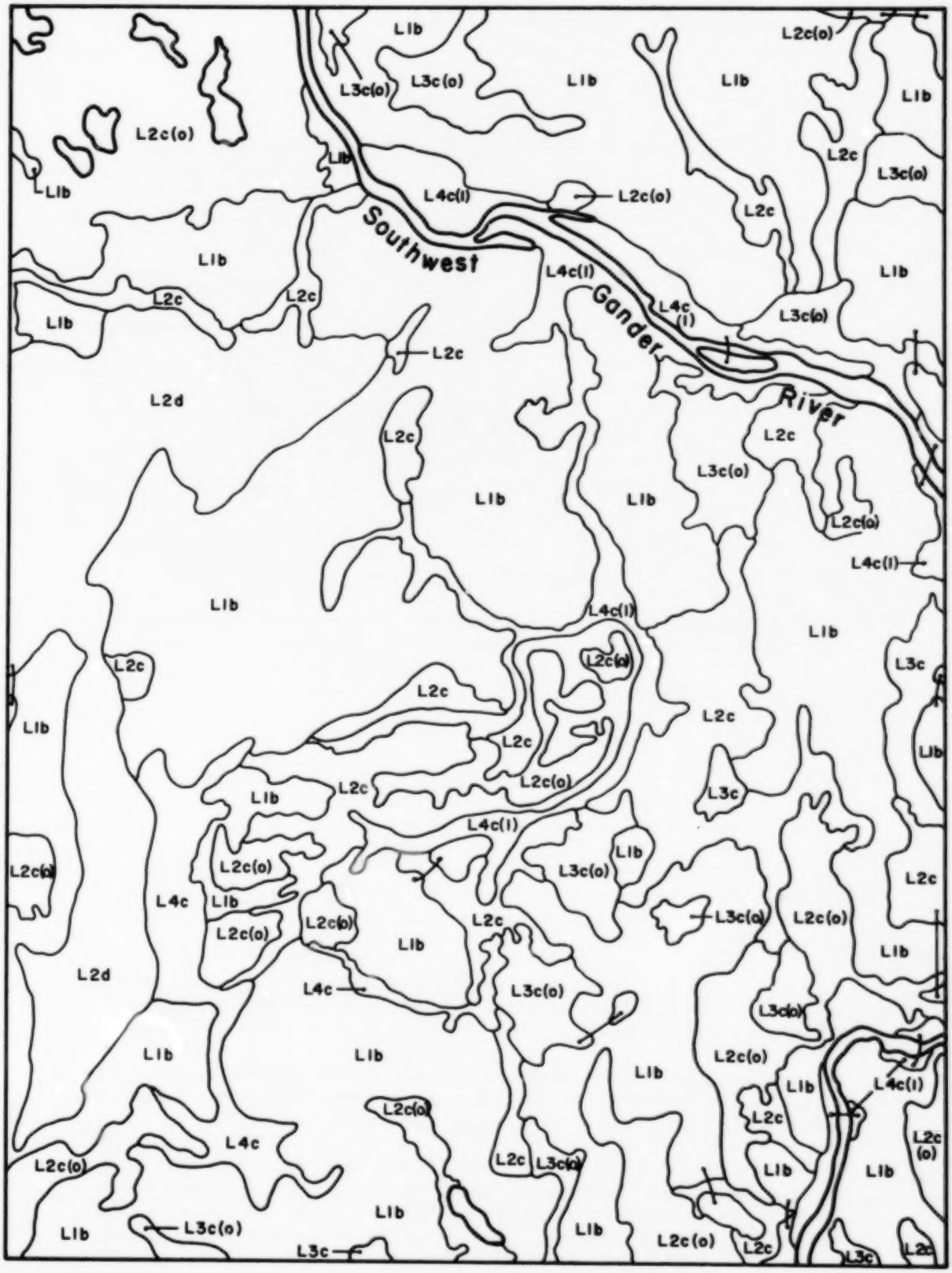
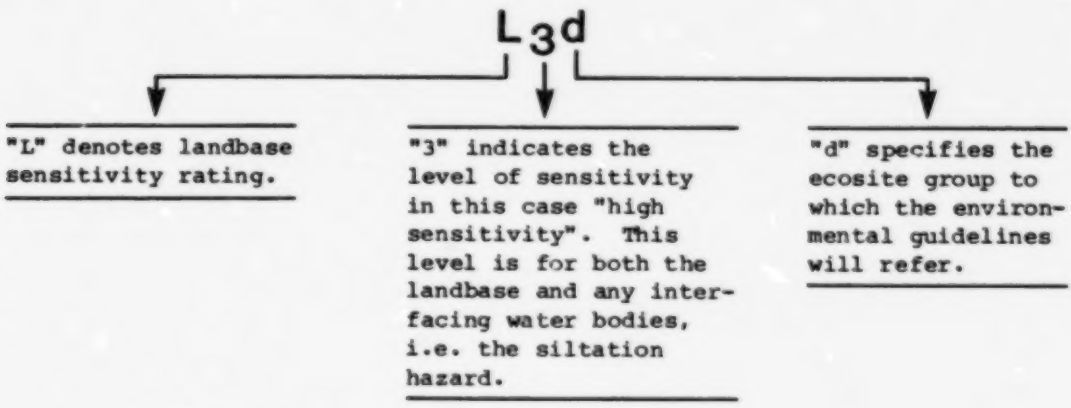


Figure 5. Example of land sensitivity mapping in central Newfoundland (Scale: 1:12,500).

The following mapping convention demonstrates the land sensitivity rating:


L3d
"L" denotes landbase sensitivity rating.
"3" indicates the level of sensitivity in this case "high sensitivity". This level is for both the landbase and any interfacing water bodies, i.e. the siltation hazard.
"d" specifies the ecosite group to which the environmental guidelines will refer.

RECOMMENDED GUIDELINES

Guidelines to be applied to logging operations and related construction activities are listed below. The list is by no means complete and as additional guidelines based upon refined knowledge are developed, they can be incorporated to address the appropriate ecosite groups. Table 4 presents the ecosite groups and the relevant site specific guidelines. The guidelines are as follows:

1. The guidelines specified in the publication "Resource Road Construction: Environmental Guidelines and Design Criteria" by R.N. McCubbin et al. (1985) will apply to all ecosite groups.

2. The higher the sensitivity level of a delineated ecosite, the more intense should be the ground survey in regard to road location and skid trail layout etc. to ensure environmental protection is implemented where it is most needed.

3. No logging, road construction, vehicle operation or related activities should be undertaken; sites should be maintained in a natural undisturbed condition.

4. Logging and road construction should not be undertaken in the spring or during excessively wet periods. Winter seasons or freeze-up periods are recommended for harvesting operations.

5. Buffer strips of undisturbed ground vegetation should be maintained in land-water interface zones; equipment should not be operated in these areas; merchantable timber may be harvested and removed from the buffer zone by winching. Buffer strip widths are specified as follows for each land sensitivity rating:

Table 4. Ecosite groups, land sensitivity levels and recommended guidelines.

Ecosite groups and subgroups	Land sensitivity level	Recommended guidelines
Group a	L_0	1, 2, 5-1
Subgroup a(m)	L_0	1, 2, 5-1
Group b	L_0	1, 2, 5-1, 10
	L_1	1, 2, 5-2, 10
	L_2	1, 2, 5-3, 10
Group c	L_1	1, 2, 4, 5-2, 9, 12
	L_2	1, 2, 4, 5-3, 9, 12
	L_3	1, 2, 4, 5-4, 9, 12
Subgroup c(o)	L_2	1, 2, 4, 5-3, 9, 12
	L_3	1, 2, 4, 5-4, 9, 12
	L_4	3, 5-6
Subgroup c(l)	L_2	1, 2, 4, 5-3, 9, 12
	L_3	1, 2, 4, 5-4, 9, 12
	L_4	3, 5-6
Group d	L_1	1, 2, 4, 5-2, 9, 12
	L_2	1, 2, 4, 5-3, 7, 8, 9, 11
	L_3	1, 2, 4, 5-4, 6, 7, 8, 9, 11
	L_4	1, 2, 4, 5-5, 6, 7, 8, 9, 11
	L_5	3, 5-6
Subgroup d(o)	L_2	1, 2, 4, 5-3, 9, 12
	L_3	1, 2, 4, 5-4, 9, 12
	L_4	1, 2, 4, 5-5, 9, 12
	L_5	3, 5-6
Group e	L_1	1, 2, 5-2
	L_2	1, 2, 5-3, 7, 8, 9, 11
	L_3	1, 2, 5-4, 6, 7, 8, 9, 11
	L_4	1, 2, 5-5, 6, 7, 8, 9, 11
Group f	L_2	1, 2, 5-3, 7, 8, 9, 11
	L_3	1, 2, 5-4, 6, 7, 8, 9, 11
	L_4	1, 2, 5-5, 6, 7, 8, 9, 11
	L_5	3, 5-6

	Sensitivity level	Ecosite groups	Buffer strip (metres)
5-1	L_0	a, a(m), b	20
5-2	L_1	b, c, d, e	20
5-3	L_2	b, c, c(o), c(l), d, e, f	30
5-4	L_3	c, c(o), c(l), d, d(o), e, f	50
5-5	L_4	d, d(o), e, f	115
5-6	L_4	c(o), c(l)	*
5-6	L_5	d, d(o), f	*

*For a sensitivity rating of L_4c(l), or L_4c(o), and all L_5 ratings guideline "3" is to be followed. If the width of the ecosite is less than 115 m, the buffer zone should include not only the natural boundary of the ecosite but an additional swath from the adjoining unit such that a 115 m buffer is maintained in the interface zone.

6. Cable logging is recommended. Where this logging method is deemed impractical because of severe economic or technological constraints, guidelines 7, 8 and 9 should be followed. These guidelines are, however, not to be used as a substitute for cable logging methodology which would be the better choice from an environmental perspective.

7. Skid trail location and construction should be planned before the harvest proceeds. Skid trails and landings should be regarded as an integral component of road layout. Upper limits of slope operability should be predetermined and marked before harvest.

8. Skid trails should cross slopes with the contour with a maximum deviation from the horizontal not exceeding 15%. Where possible, harvested timber should be winched in from points along the skid trails. Machine activity on steep slopes should be planned to ensure minimum disturbance to vegetation on the slopes and thus reduce surface erosion.

9. On wetter sites the number of machine passes per trail should be minimized.

10. Skid trail numbers should be maximized with a minimum of passes per trail, reduction of soil compaction being the desired effect.

11. Where possible, logging should be carried out by the direction of cut proceeding from the upslope to downslope position. Cutting the upper reaches of the slope and moving downslope ensures that any movement of eroded surface materials from upper slope positions will be buffered by the vegetation still present on the lower slope positions.

12. Landings should not be located within this ecosite group.

CONCLUSIONS

The land sensitivity mapping system is presented as a simple methodology which can be applied using conventional air photo interpretation to determine relative land sensitivity in terms of readily identifiable parameters. Although the system is provisional and refinements are likely as a result of further field testing, the approach and methods should provide a practical framework for addressing environmental concerns inherent in the planning phases of a logging operation.

Adherence to the recommended guidelines will promote considerable reductions in the level of on-site disturbance associated with logging operations. At the planning stage such maps could have additional applications in the environmental impact assessment process. Finally, such a mapped data base, which would remain stable and not need periodic revision, could serve for more detailed studies regarding the quantitative aspects of soil erosion and land sensitivity for different site types.

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APPENDIX I

Relative Soil Erodibility

It is known that for various surficial landforms certain textural ranges of soil can be inferred in light of past and presently occurring processes. The identification of specific genetic categories of landforms can therefore provide a basis for predicting soil texture and consequent erodibility levels. However, the range of soil textures associated with different categories of landforms is often wide, with intra- and inter-category overlaps being common. These naturally occurring overlaps necessitate definition of relative soil erodibility within a minimum number of levels to facilitate an application through air photo interpretation.

Four levels of relative soil erodibility have been designated:

E_0 - None
E_1 - Low
E_2 - Moderate
E_3 - High

The relationships of these erodibility levels to pedologic and geomorphic conditions are shown in Table 3.

APPENDIX II

Slope Classes

Six slope classes have been utilized:

S_0 - negligible (0-5%)
S_1 - low (6-15%)
S_2 - moderate (16-30%)
S_3 - high (31-45%)
S_4 - very high (46-60%)
S_5 - extreme (> 60%)

Two general slope forms are recognized when determining the gradient: simple slopes and complex slopes. Simple slopes rise uniformly from a minimum elevation to a maximum, which is clearly discernible at a point where the summit morphology becomes dominant. Simple slopes are also characterized by few significant breaks in gradient. The gradient of a simple slope can be estimated from the change in elevation and expressed as a percent.

Complex slopes are series of slopes, summits and intervening valleys which reoccur in recognizable patterns of symmetry and/or asymmetry, which distinguishes them from other landscape features. The slope class for such complex patterns can be estimated as the average gradient of the major components comprising the pattern expressed as a percent.

APPENDIX III

Groundwater Classes

The term "groundwater" has been used generally in this report and includes the following conditions:

1. True groundwater, the level of which undergoes vertical fluctuation in the soil profile and can thus influence the zone of aeration.

2. Interflow (also referred to as subsurface flow or seepage) in which lateral movement of soil water is dominant and percolation to the true groundwater table is restricted by indurated soil layers or bedrock.

3. Perched soil water resulting from restriction of percolation and lateral movement due to topography, indurated soil layers or lithic contacts.

4. Periodic inundations of significant duration arising from:

   a. increases in stream and lake levels during periods of high precipitation or storage (ice and snow melt) inputs.

   b. intermittent and ephemeral stream flow and any associated surface accumulations resulting from direct and storage inputs.

Three groundwater classes and one subclass are recognized: G_0, G_1, G_2 and $G_2(i)$.

Groundwater Class G_0 - Characterized by an absence or near absence of true groundwater, interflow or perched soil water in the soil profile. Soils are very rapidly to moderately well drained, soil moisture content does not usually exceed field capacity except for short durations after heavy rainfalls. The true groundwater table and capillary fringe are usually present at deep levels below the taxonomic profile.

Groundwater Class G_1 - Characterized by a predominant interflow of soil water. Lateral seepage is largely controlled and maintained by gradient, slope length and the presence of indurated soil layers or bedrock. Vertical percolation is restricted resulting in soil moisture contents which are in excess of field capacity for long periods of the year. Soil drainage ranges from moderately well to poorly drained.

Groundwater Class G_2 - Characterized by restricted lateral seepage and vertical percolation, thus leading to the development of a perched soil water condition. Soil moisture typically exceeds field capacity for long periods of the year with imperfect to very poorly drained and anaerobic soil conditions being prevalent. Subclass G_2 (i) is characterized by soils which are subjected to periodic inundation. Soil moisture and drainage conditions in these soils is complex and variable due to the temporal relationship between inputs and the response of the true groundwater table. However, the true groundwater table is generally close to the surface resulting in soils with moisture contents above field capacities and characterized by imperfect to very poor drainage.

APPENDIX IV

Ecosite Groups

Six ecosite groups and four subgroups have been recognized. A descriptive summary of the ecosite groups and subgroups is presented below:

Group a and Subgroup a(m) - Characterized by ecosites with exposed bedrock surfaces. Non-soil cover, i.e., unconsolidated material less than 10 cm in depth can occur and soil cover if present would be less than a 25% inclusion in the map unit. No differentiation on the basis of rock type or form is undertaken with the exception of subgroup a(m) which is separated on a morphological basis. This subgroup is characterized by oversteepened bedrock surfaces subject to natural geologic mass wasting. Talus and other unconsolidated products of mass wasting are an integral component of the subgroup. Drainage of these sites is primarily by means of surface runoff and is rapid to very rapid, thus restricting the development of perched groundwater or lateral seepage conditions.

Group b - Characterized by ecosites with negligible to low, short, simple and complex slope patterns. Parent materials are predominantly morainal and glaciofluvial but other genetic categories can be expected. These sites exhibit moderately well to very rapid drainage. Percolation is dominant on deep, coarse to moderately coarse textured soils. On thinner soils where bedrock restricts percolation, subsurface flow can occur at the soil-rock interface. Such interflow is often discontinuous because of variability in soil depth and irregularity in the morphology of the bedrock substrate. The short slopes and complex slope patterns combined with the irregularity of the bedrock substrate effectively prevent the build-up of a continuous and dominant lateral seepage condition in these sites. Thus, group b is characterized by the G_0 groundwater class.

Group c and Subgroups c(o) and c(l) - Characterized by ecosites with negligible to low, short, simple and complex slope patterns. The dominant genetic categories in this group include morainal, alluvial and organic materials. Imperfect to very poorly drained conditions are dominant due to perched soil water or fluctuating true groundwater table. Perched soil water conditions develop in topographic basins where soil moisture accumulates and percolation is restricted by lithic contacts or impervious soil layers. In such areas evapotranspiration and drainage outputs are generally less than inputs from precipitation and runoff from the surrounding landscape. Thus the perched condition is characterized by saturated soils

and moisture contents exceeding field capacity throughout the year. Fluctuating true groundwater tables are common on active floodplains which are subjected to periodic inundations. Subgroup c(o) is to be used with organic soils, whereas, subgroup c(1) is to be used with alluvial mineral soils.

Group d and Subgroup d(o) - Characterized by ecosites with generally long simple slopes which promote a lateral downslope subsurface flow of soil water. The primary parent materials are morainal and/or colluvial having a variable textural range. Seepage of soil water is promoted by the presence of fragipans in the solum or by uniform and impervious bedrock substrates. Upper portions of the slope tend to be moderately well drained, whereas, middle and lower slope positions are imperfectly to poorly drained due to a reduction of slope gradient and an accumulation of soil water. Subgroup d(o) is used to designate organic soil deposits which develop and are maintained on slopes by the presence of the lateral seepage of groundwater.

Group e - Characterized by ecosites with short, simple and complex slope patterns. The primary parent materials are morainal deposits. These sites are moderately well to rapidly drained with no significant buildups of subsurface flow. The short steep slopes combined with the complex slope patterns, effectively restrict the development of dominant seepage of soil water. Thus, group e is characterized by the G_0 groundwater class.

Group f - Characterized by ecosites with steep slopes and perched soil-water or true groundwater tables. Such sites are unlikely to occur under natural conditions, since the prevailing slope conditions would restrict their development.